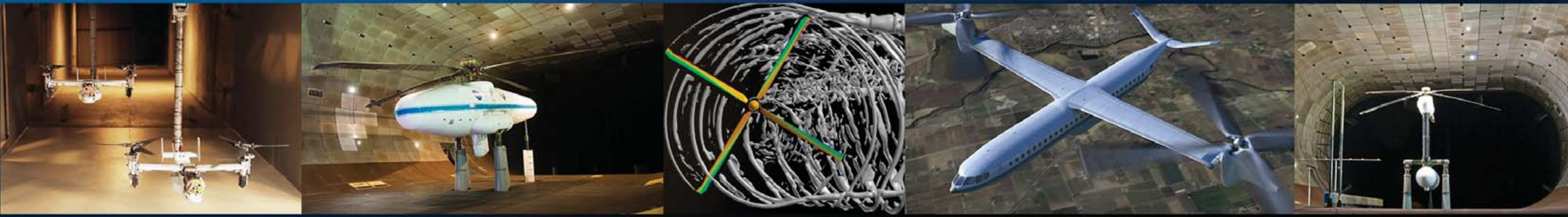
UH-60A Airloads
Wind Tunnel Data Update

Tom Norman

Airloads Workshop
August 21, 2013



Outline

- Recent/Upcoming Airloads Publications
- Recent/Current NASA Activities
- High Advance Ratio Data Release
- Bonus Test Information
  - Mean lag comparisons with analysis

Recent/Upcoming Airloads Publications

- AHS Forum (4)
  - "Retroreflective Background Oriented Schlieren of Tip Vortex Visualization and Mapping for UH-60 Airloads", Schairer et al
  - "FUN3D Airload Predictions for the Full-Scale UH-60A Airloads Rotor in a Wind Tunnel", Lee-Rausch et al
  - "Effects of the Fuselage and Tunnel Walls on Correlation of CFD/CSD Computations and Test Data", Floros et al
  - "Investigation of the UH-60A Slowed Rotor Wind Tunnel Tests using UMARC" , Bowen-Davies et al
- AIAA Applied Aero Conference (1)
  - "Comparison of Computed and Measured Vortex Evolution for a UH-60A Rotor in Forward Flight", Ahmad et al
- September ERF (1)
  - "Performance and Loads Predictions of a Slowed UH-60A Rotor at High Advance Ratios", Potsdam et al

Recent/Current NASA Activities

- NASA's NSC Knowledge Now website (Airloads data storage) updated in April 2013
  - New security protocols require all NSCKN users have "NASA Identity"
  - Account holders must be US citizens
  - All eligible Airloads account holders offered opportunity to transfer to new system in April – most people transferred
  - NSCKN will be site for future Airloads data releases
- Continuing data evaluation/reduction efforts for rotor data, Blade Displacement, PIV, and RBOS
  - Data processing/reduction improvements continue
    - Still have some work to do – work with CFD analysts providing valuable insights
  - Working to identify data release dates for BD, PIV, and RBOS data
    - FY14 Target dates to be determined soon

Recent/Current NASA Activities

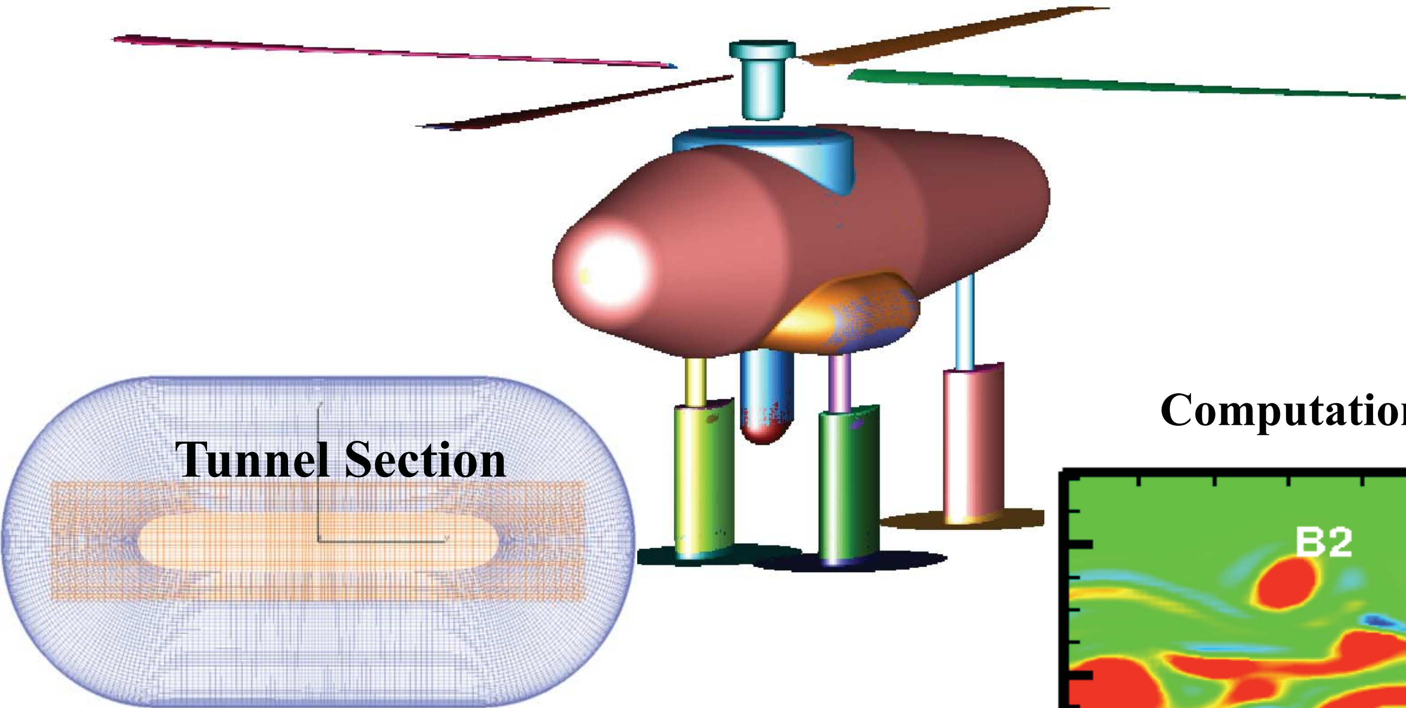
- FUN3D validation efforts (Biedron/Lee-Rausch)
  - Completed speed-sweep computations for 2013 AHS Forum paper
    - With and without LRTA
    - Free air vs tunnel
    - Trim tab vs no trim tab
  - Performed computations for blade deflection (R42P60)
    - Compared airloads, pressures, and deflections

  - See Bob Biedron’s presentation

Recent/Current NASA Activities

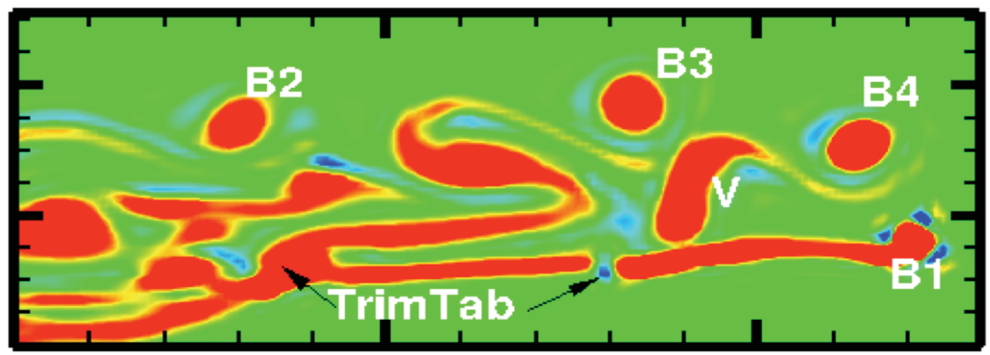
- OVERFLOW validation efforts
  - Calculated effects of wind tunnel and LRTA on rotor loads and performance (Chang)
    - Results documented in January 2013 AIAA paper
    - Currently evaluating effects of higher-resolution CAMRAD models (January 2014 AHS Specialist Mtg)
  - Performing computations for comparison with blade deflection measurements (Romander)
    - Paper planned for January 2014 AHS Specialist Mtg
  - Performing computations for comparison with PIV measurements (Ahmad)
    - Initial results documented in June 2013 AIAA paper
    - Expansion of effort underway

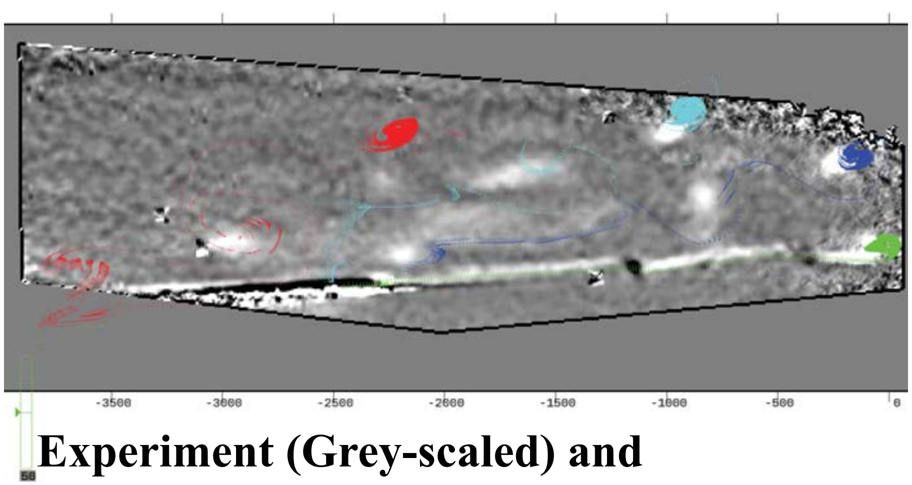
Computed and Measured Vorticity Field for Rotor in Free air and in Tunnel



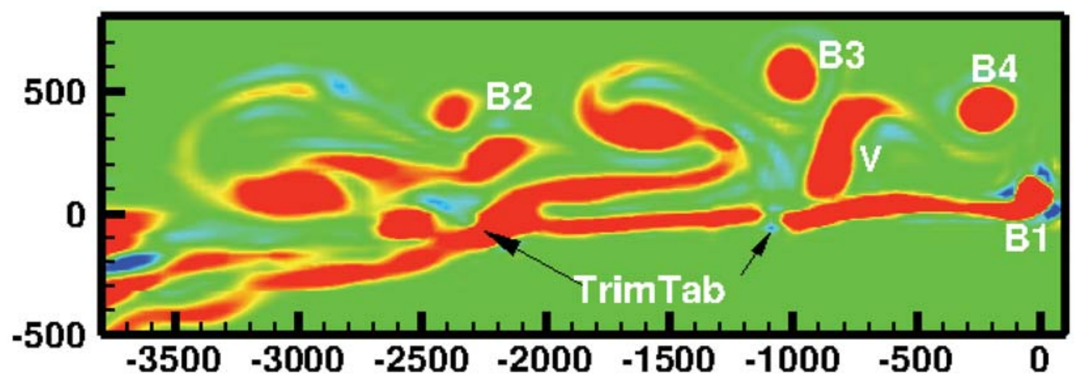
Grid points
Free Air: 360m
WT: 221m

Computation: Free Air (wall corrected)



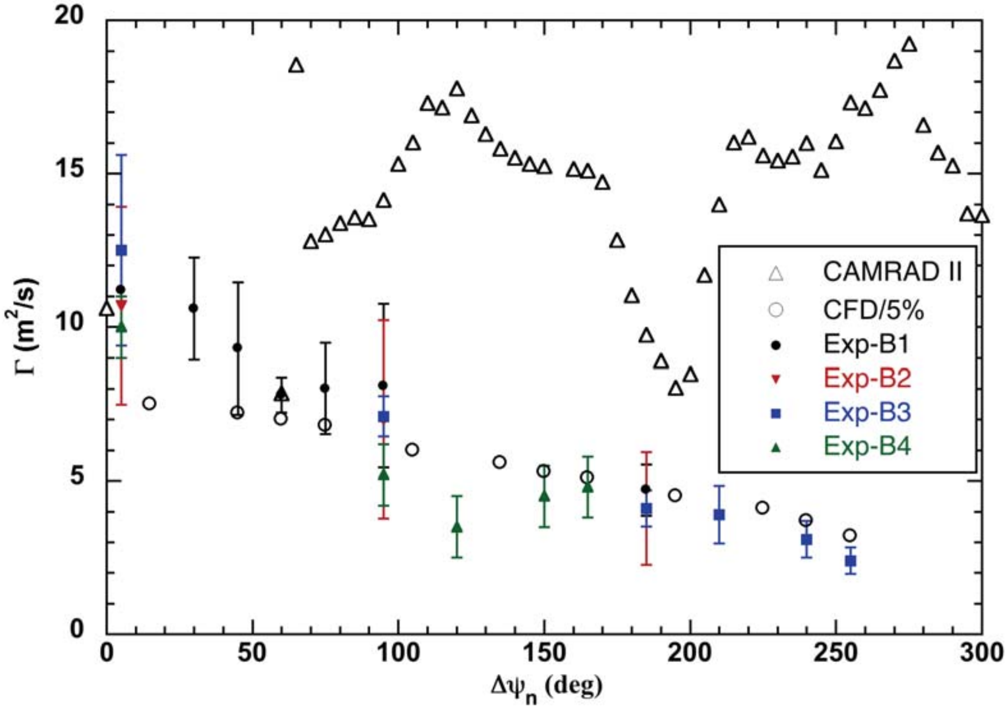


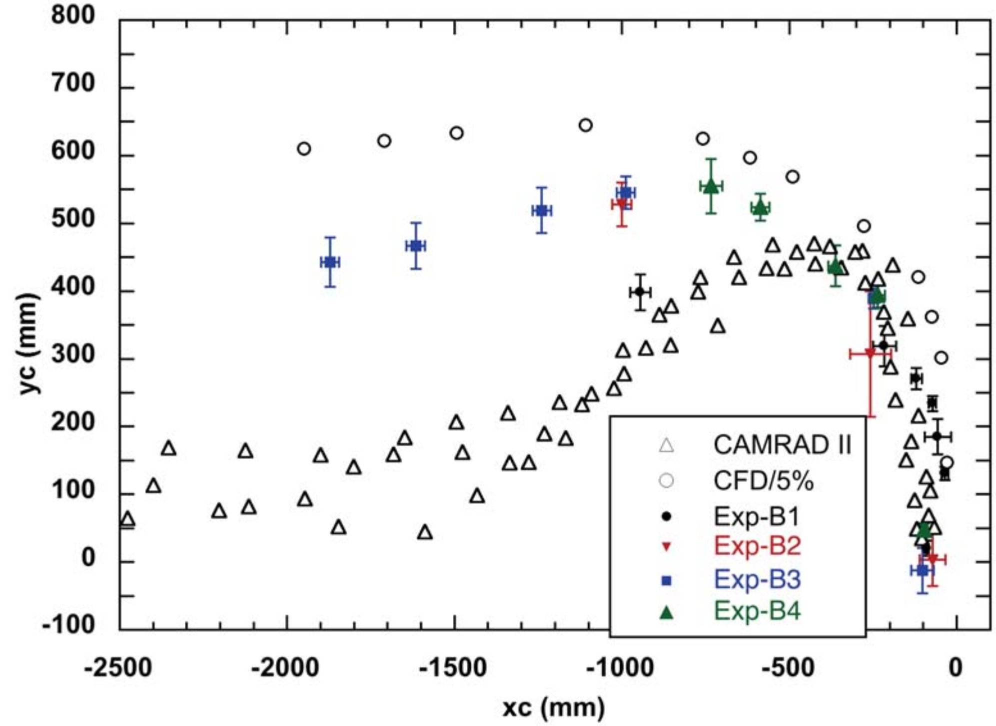
Experiment (Grey-scaled) and CFD (colored by blades) superimposed



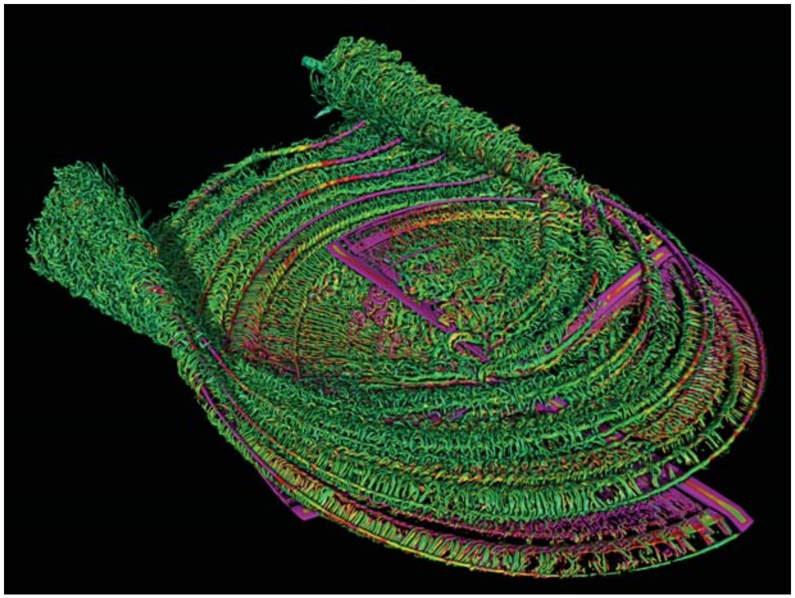
(c). Computation: WT

Vortex Evolution of Helicopter Flowfield in Forward Flight





- **The CFD simulation captures the key features (number of vortices, shear layer, trim tab vortices) of the complex measured rotor wake**
- **The computed vertical locations of vortices were consistently higher than the measured location**
- **CFD shows continuity between vortices and the shear layers more distinctly than measurements**
- **CFD underpredicts circulation for $\Delta\psi < 90$ deg suggesting that a finer grid spacing is needed to capture vortex formation and roll-up**



High Advance Ratio Data Release

- Preparing to release high advance ratio data to NSCKN
- Full NASA database contains 232 data points
  - 47 pts at Mtip=0.65 (100% RPM)
  - 36 pts at Mtip=0.42 (65% RPM)
  - 149 pts at Mtip=0.26 (40% RPM)
- Proposed data release to include
  - Statistical data (excel spreadsheet) with data from all data points
  - Full data point files (statistical + time histories) for limited number of points

Suggested High Advance Ratio Points

Table 1. Slowed rotor test runs

Run no.	% NR	α_S	V	μ	M_A	θ_{75}
R66	100	0.0	130	0.3	0.85	−0.1 to 10.0
		2.0				0.0–9.9
		4.0				−0.1 to 5.9
R69		0.0	172	0.4	0.91	0.4–7.9
		2.0				−0.1 to 8.0
		4.0				0.0–5.9
R87	65	0.0	83	0.3	0.55	−0.1 to 7.9
			111	0.4	0.59	−0.1 to 7.9
			139	0.5	0.63	−0.1 to 7.9
			167	0.6	0.67	0.0–7.9
R91	40	0.0	52	0.3	0.34	0.0–8.0
			69	0.4	0.36	−0.1 to 8.0
			87	0.5	0.39	0.0–8.0
			104	0.6	0.42	0.0–7.9
			121	0.7	0.44	0.0–8.0
			139	0.8	0.47	−0.1 to 8.0
			157	0.9	0.49	0.0–4.0
			174	1.0	0.52	−0.1, 0.9, 1.9
R96		2.0	52	0.3	0.34	1.7, 1.9
			70	0.4	0.36	1.9
			87	0.5	0.39	1.9
			104	0.6	0.42	2.0
			121	0.7	0.44	1.9
			139	0.8	0.47	1.9
			156	0.9	0.49	1.9
			174	1.0	0.52	0.9
R93		4.0	52	0.3	0.34	0.0–8.0
			70	0.4	0.36	0.0–8.0
			87	0.5	0.39	−0.1 to 8.0
			104	0.6	0.42	0.0–8.0
R95			52	0.3	0.34	0.9, 1.1
			104	0.6	0.36	0.0, 2.0, 3.0
			121	0.7	0.44	−0.1 to 7.7
			138	0.8	0.47	−0.1 to 7.7
			156	0.9	0.49	−0.1 to 6.2
			173	1.0	0.52	0.0, 2.0

Suggested High Advance Ratio Points

Table 2. Test points for rpm sweeps at two different advance ratios and advance ratio sweeps at 40% nominal rpm at two different shaft angles

Point	M_T	α_S	μ	θ_{75}	C_T/σ	T	θ_{1C}	θ_{1S}
rpm sweeps								
$\mu = 0.3$								
6619	0.65	0.0	0.3	6.0	0.0815	18407	0.4	−4.6
8716	0.42	0.0	0.3	5.9	0.0806	7797	1.6	−5.1
9117	0.26	0.0	0.3	5.9	0.0815	3033	2.6	−5.3
$\mu = 0.4$								
6912	0.65	0.0	0.4	6.0	0.0712	15880	−1.1	−4.8
8724	0.42	0.0	0.4	5.9	0.0699	6720	0.5	−6.3
9125	0.26	0.0	0.4	6.0	0.0722	2679	1.7	−6.5
μ sweeps								
$\alpha_S = 0°$								
9116	0.26	0.0	0.3	4.0	0.0622	2307	1.5	−4.0
9133	0.26	0.0	0.5	6.0	0.0633	2338	0.9	−7.4
9145	0.26	0.0	0.6	7.9	0.0622	2277	0.3	−10.1
$\alpha_S = 4°$								
9318	0.26	4.0	0.4	2.0	0.0627	2315	0.7	−4.0
9325	0.26	4.0	0.5	2.0	0.0628	2312	0.1	−4.8
9518	0.26	4.0	0.7	3.0	0.0616	2235	−0.8	−6.9
9528	0.26	4.0	0.9	6.2	0.0634	2280	−3.1	−11.6

Table 3. Test points for thrust (collective) sweeps at two shaft angles and three advance ratios

Point	M_T	α_S	μ	θ_{75}	C_T/σ	T	θ_{1C}	θ_{1S}
$\alpha_S = 0°$								
$\mu = 0.8$								
9155	0.26	0.0	0.8	−0.1	0.0201	727	−2.8	−0.5
9156	0.26	0.0	0.8	2.0	0.0329	1192	−2.8	−3.0
9157	0.26	0.0	0.8	4.0	0.0340	1227	−2.9	−5.9
9158	0.26	0.0	0.8	6.0	0.0404	1459	−2.9	−8.3
9159	0.26	0.0	0.8	8.0	0.0446	1618	−2.6	−10.8
$\mu = 0.9$								
9162	0.26	0.0	0.9	0.0	0.0205	736	−3.7	−0.3
9163	0.26	0.0	0.9	2.0	0.0235	844	−4.0	−3.0
9164	0.26	0.0	0.9	4.0	0.0259	930	−4.4	−6.0
$\mu = 1.0$								
9168	0.26	0.0	1.0	−0.1	0.0193	688	−4.8	0.0
9175	0.26	0.0	1.0	1.9	0.0220	784	−5.1	−2.7
$\alpha_S = 4°$								
$\mu = 0.8$								
9520	0.26	4.0	0.8	−0.1	0.0468	1697	−2.1	−3.5
9521	0.26	4.0	0.8	1.9	0.0556	2014	−1.9	−5.9
9522	0.26	4.0	0.8	5.9	0.0692	2504	−1.7	−11.0
9523	0.26	4.0	0.8	7.7	0.0760	2749	−1.4	−13.0
$\mu = 0.9$								
9526	0.26	4.0	0.9	−0.1	0.0576	2064	−3.1	−3.2
9527	0.26	4.0	0.9	2.0	0.0595	2151	−3.4	−6.2
9528	0.26	4.0	0.9	6.2	0.0634	2280	−3.1	−11.6
$\mu = 1.0$								
9531	0.26	4.0	1.0	0.0	0.0609	2170	−4.0	−3.3
9530	0.26	4.0	1.0	2.0	0.0585	2085	−4.6	−6.4

- From Datta (AHSJ 2013), 32 pts
- Potsdam (ERF 2013) also looked at coll sweeps at mu=0.4 and 0.6 (Run 91), 7 more pts

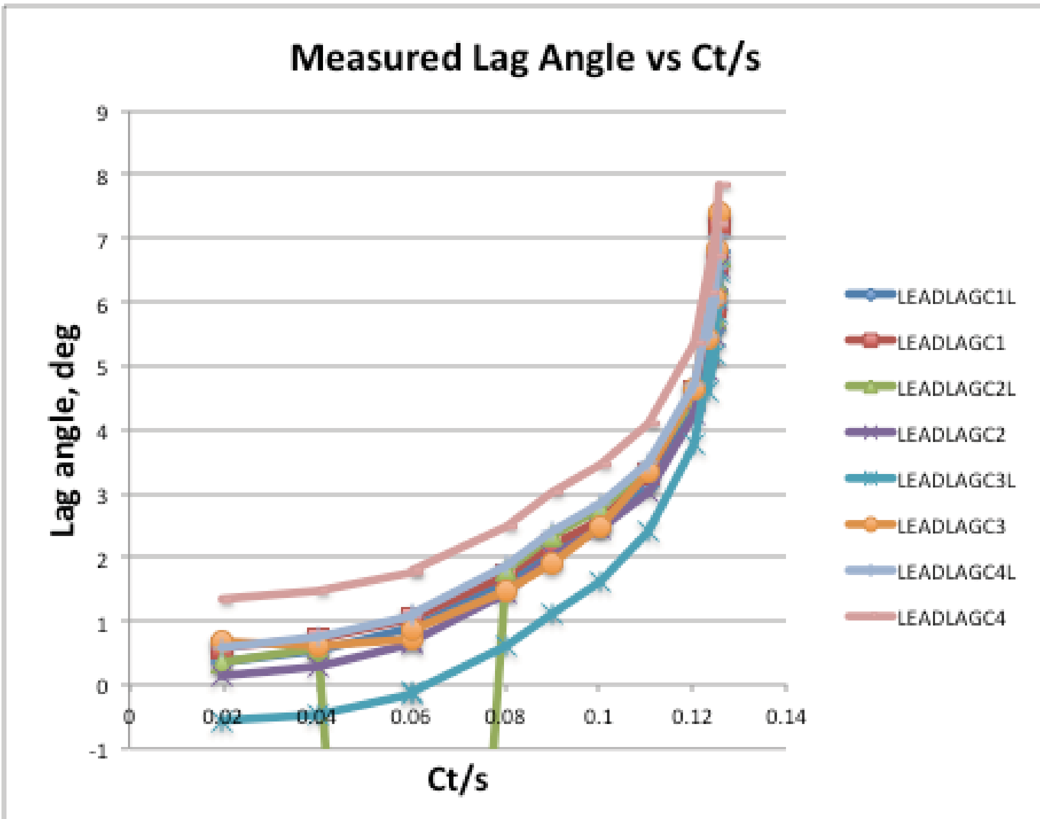
Mean Lag Comparisons

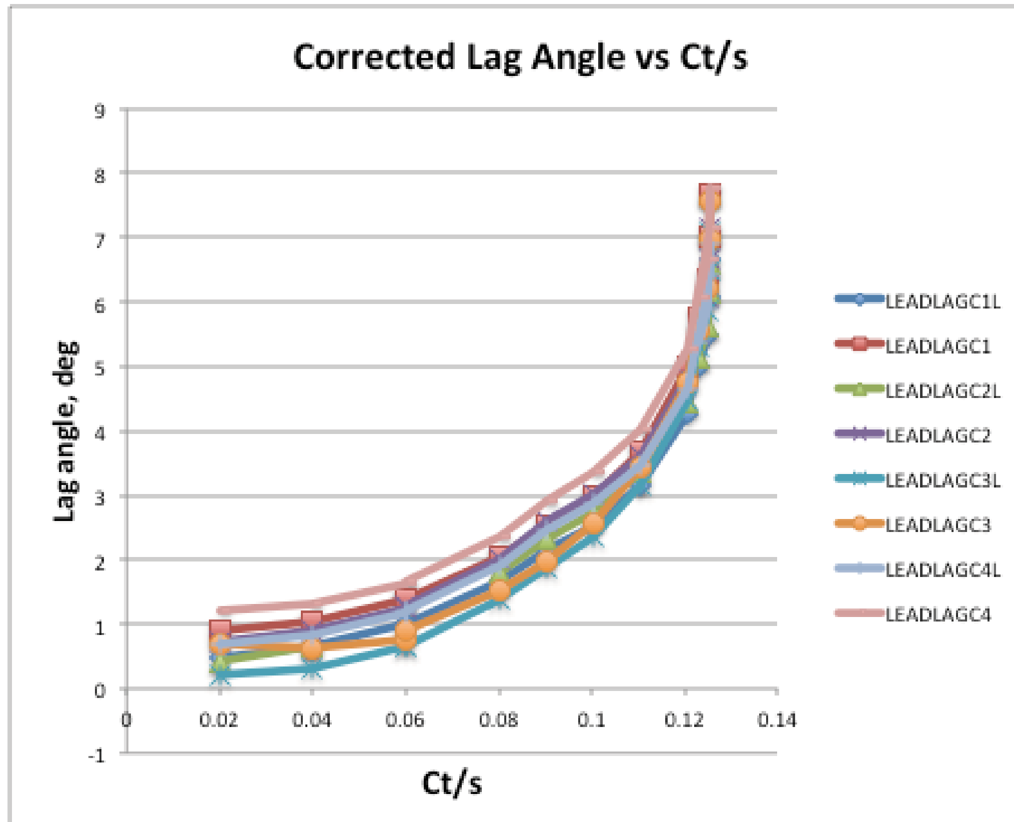
- Two independent systems (crabarm, laser) used to measure blade root motion during WT test

- Test data showed blade to blade and method to method differences- especially for the mean
  - Have identified a number of possible causes for the differences (amplifier drift, offsets, RPM/CF effects)
  - Still evaluating which corrections to apply
    - Working with analysis, BD, and PIV data to help guide decision

Mean Lag Comparisons

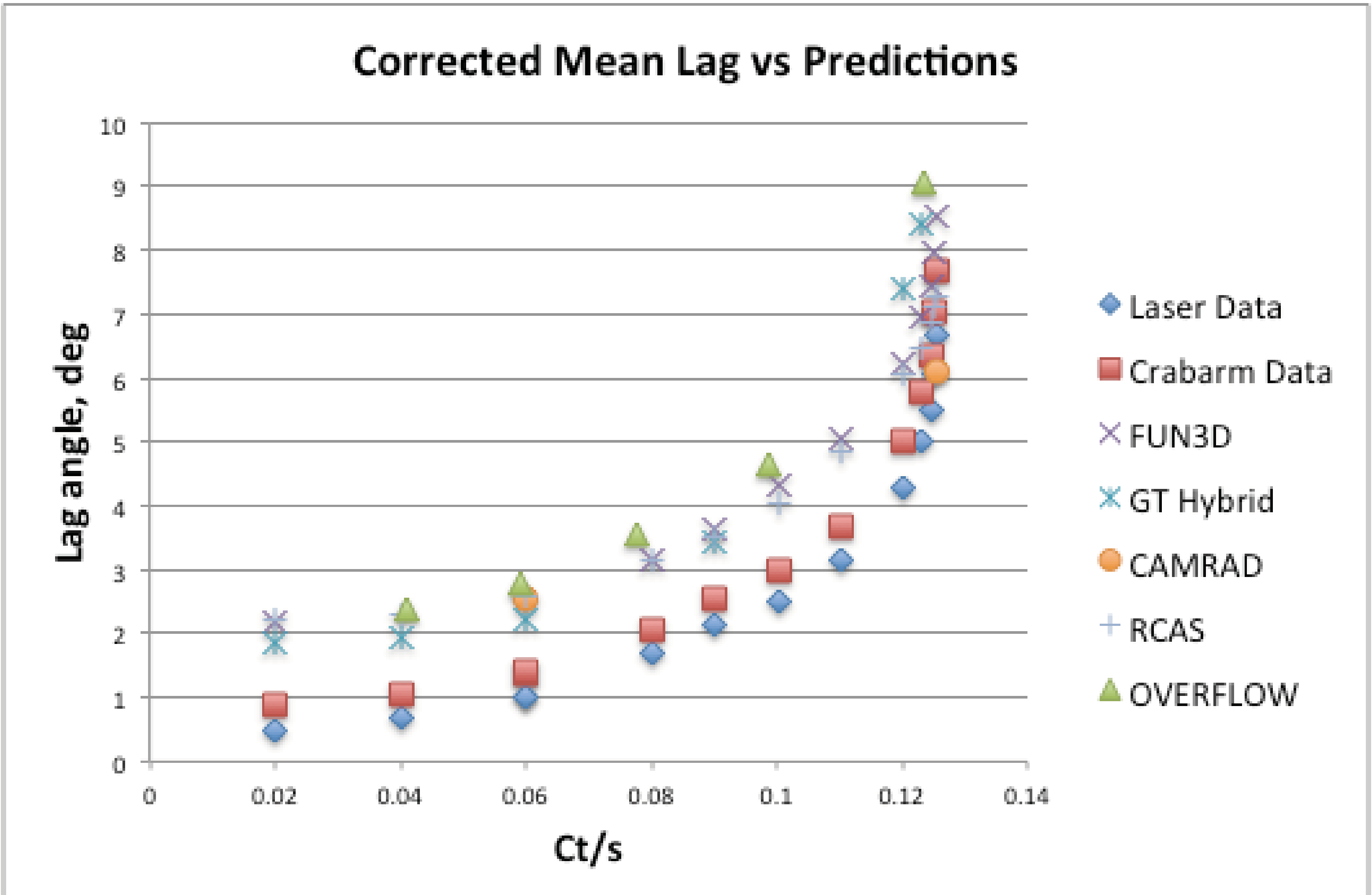
- Measured vs Corrected Mean Lag Angle for Thrust Sweep
  - Reduced scatter (note: corrections are preliminary)





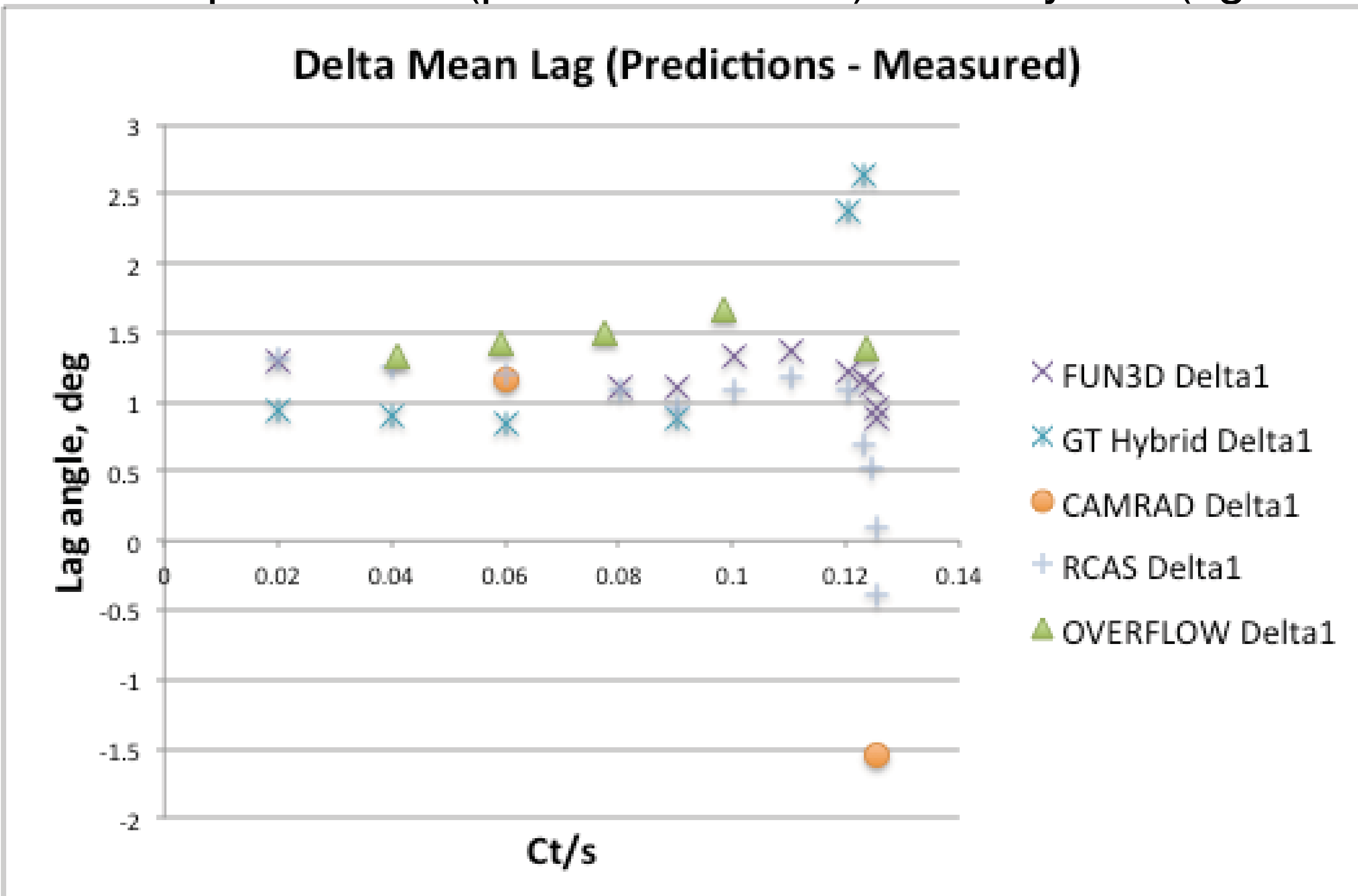
Mean Lag Comparisons

- Corrected Mean Lag vs Predictions for Thrust Sweep
  - Predictions consistently show greater lag than measurements



Mean Lag Comparisons

- Delta Mean Lag (Predictions – Measured)
  - Relatively constant offset up to high thrust
  - Is error experimental (poor corrections) or analytical (cg location)?



NASA